PLANETARY SCIENCE, ASTROBIOLOGY, AND THE ROLE OF SCIENCE AND EXPLORATION IN SOCIETY

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The basic research done by members of the A.G.U. plays an important role in our society. However, there is remarkably little discussion here or elsewhere of what this role is and how we as individual scientists and as a community of academicians and researchers contribute to the broader society. The role of science in society today is both complex and poorly defined. This is seen, for example, in the Kansas Board of Education's removal of evolution from the statewide high-school exams and in the ongoing debate about creation versus evolution. Certainly, there often is a general lack of understanding by part of the public as to what constitutes "science" and what separates it from other activities.

What is the role of science in society today? What is the rationale for public support for basic research? What should the scientific community be doing to better elucidate this role?

We would like to address these questions using examples from the fields with which we are most familiar—planetary science and astrobiology. Our goal is to stimulate a broader discussion of these issues. As with the science itself, the discussion is as important as the conclusions.

What drives planetary science?

We highlight three observations about planetary science and astrobiology as basic (as opposed to applied) research endeavors:

First, planetary science and astrobiology, along with related fields such as astrophysics, are fields that have very few practical applications. While there is some practical relevance—such as determining the distribution of asteroids in order to protect the Earth from *Deep Impact* or *Armageddon*, or using the Mars and Venus climate to better understand what controls the Earth's climate—these issues alone are not the fundamental drivers of research in planetary science. They are not necessarily the central scientific issues in the field, and the spacecraft missions that are being proposed and flown are not designed specifically to address those issues that might be most practical.

Second, the support that planetary science has from the scientific community and from the public is much larger than is commensurate with their practical applications. The evolving field of astrobiology is similar, in that the compelling aspects of the field that garner the most public support—whether there is life elsewhere and whether we are alone in the universe—are those that appear to have the least practical value.

Third, while new spacecraft missions in planetary science are designed to address important questions about planets and our solar system, answering a single set of questions will not end our desire to explore the planets. Rather, it brings up additional questions, and new research results constantly build on and revise our present understanding. Although the nature of the questions changes, we will never be able to learn enough about Mars, about our solar system, or about the rest of the universe. This pattern has been with us for a long time—even the theories of Copernicus and Newton have been modified by subsequent researchers to be consistent with new observations and concepts.

Apparently, the driver behind planetary exploration is not a desire to have specific answers to the specific questions that we are asking today. Rather, the exploration of the planets is driven by something else, and that something is likely the "exploration" itself.

Why do we explore?

Our goal in looking to the planets—and more broadly in exploring the fields of astrobiology and astrophysics, for example—is to understand the nature of the world around us. These are practically universal questions, both to science and to the public. In exploring our universe, we are looking for answers to questions about how the universe formed and evolved; how galaxies and stars form, evolve, and die; how planets form, how they behave, how they evolve, and whether they are widespread; whether Earth-like planets are common; how life forms and whether microbial life exists elsewhere; and whether intelligent life is rare or common in the universe.

These are questions that touch us deeply as humans: What are the characteristics of the solar system and the universe? How do these properties of our world relate to us, and how do we fit into the world? One of the hallmarks of western civilization is that we are an exploring society. Much of the last two millennia have been marked by our desire to understand the nature of the world around us. This desire is often expressed as a curiosity about the world, but what drives this curiosity? By understanding the boundary conditions that describe our world, we are understanding the boundaries defining who we are. In this context, exploring the universe is no different than exploring the arts, literature, the humanities, or the psychology of the mind, for example. By exploring and understanding the world around us and how it affects us, we are learning about ourselves and, in effect, finding out about what it means to be human.

The reasons that peoples and societies have explored have varied widely. Riches, fame, to be the first, to discover, and even to learn, have all been driving forces. Historically, however, the leading societies of the world all have supported exploration in the broadest sense. A case can be made that, when they stopped exploring, those societies were overtaken by others more willing and able. China, Portugal, Spain, Holland and England all had rich, vibrant societies that in their times led the world in art, music, science, engineering and commerce at the same time that they were exploring the world. When each of these societies stopped exploring, their overall world leadership diminished.

This connection between exploration and a vibrant, leading society is not necessarily one of "cause and effect"; exploration likely is one indicator of the vigor of a society, rather than its root cause. However, it does suggest a link between that society and the science and exploration

it conducts. Exploration may provide society with an outlet for discovery. It provides the "what if..." of an open, expansive future. It may provide the "anything is possible" dream. The public success of the Mars Pathfinder mission exemplifies this connection. In a sense, much of the world participated as a rover explored the martian surface in July, 1997. In the past 40 years, few positive events have managed to capture the imagination of the world in such a shared experience. The communal exploration of Mars, as with the Apollo Moon landing in 1969, was a moment where much of the world got to celebrate together the exploration of a new and different world.

The changing nature of the role of science in society

Over fifty years ago, on the heels of the important role of science and technology in the outcome of World War II, presidential advisor Vannevar Bush wrote a report on integrating science into society and on the important role of science in the ongoing development of the country (1). The report led directly to a dramatic increase in federal support of research and graduate education and to the creation of the National Science Foundation. Substantial government funding became available to basic researchers in academic settings such as universities and national laboratories, to allow them to focus their attention on science and technology and to train the next generation of scientists. Several generations of academicians operated under the new rules of "science is good, technology is good". The argument of "good science" was all that was necessary to obtain financial and intellectual support; there was no need to debate further what the role of science in society was or should be. As the post-World-War-II era segued into the Cold War, again the importance of science and technology to society was not questioned. By being preeminent in science and engineering, we were trying to show the world that we and our system were superior.

While science and technology are playing an even more important role in our society today, the end of the Cold War has changed the nature of this role. As described by Congressman Vernon Ehlers' recent report on updating the national science policy (2), the role of science has evolved to emphasize, in addition, economic development and independence and the ability to address issues in our country (and in the world) that have scientific and technological solutions. It explicitly emphasizes the economic benefits that can result from an investment in scientific

research. One result is that the argument of "good science, good technology" no longer seems to apply in the same way that it once did. Even basic research often is forced to find some grounds on which to justify its existence, and much basic research has no apparent or immediate tangible benefits to which it can point. In these times of increasingly tight budgets, Congress is often perceived as seeing basic research as just another constituency.

Science and the public

The science community has little experience in discussing the role of science in society and the value of science to the public. In part, this is because it has not had to do so in the fifty years since the Bush report. In fact, we often are unable to explain the role of science in society even to ourselves.

There is an increasing focus today on outreach and the public, however. For example, there is pressure for every proposal to NASA to have an "education and outreach" component. And, the highest-level NASA documents describing the goals of planetary exploration (for example, the "Roadmaps" in the NASA Office of Space Science [3,4]) emphasize some of the same philosophical drivers as interest the public—the search to understand our origins (in every sense) and the potential for life elsewhere.

Despite this, there appears to be a real stigma in the science community against addressing the societal relevance or significance of our work. Some colleagues have expressed an explicit fear that their substantial outreach activities will become known and have a negative impact on their careers. Others have commented that to emphasize these areas will be perceived as going "soft on science", or they dismiss discussions of these ideas as irrelevant.

While it is acceptable to spend a few per cent of one's research efforts and dollars on outreach, or to appeal to the high-level goals of space science in order to justify our programs, we are given the implicit message not to spend too much time and effort on outreach. If someone spends a significant amount of their professional time on education, outreach, or interactions with the public, this message becomes explicit as their scientific credentials are questioned.

In addition, there is a "disconnect" between the scientists and the public. Scientists often hold the view that they know better than the public what the important questions are, or they believe that their concerns are more important than those of the public.

What we say and what we really mean

A common response to raising some of these issues with colleagues, though, has been for them to treat the issues seriously and to respond with thoughtful comment and useful discussion. Our sense is that a large fraction of the community is legitimately engaged by the same questions as the public and would like an opportunity to discuss them openly. The combination of the lack of a venue appropriate for this type of discussion and the overt stigma associated with dealing with these issues keeps many from doing it.

The role of basic science as a means of exploring the world around us and of understanding the relationship between our world and ourselves immediately puts the role of public outreach into a different perspective. Taking the results back to the public and explaining the nature of science and of our results is not just a good service activity to be marginally encouraged or a means of increasing public support so that they will continue funding our research. Rather, it should be an integral part of doing the research: If our goal is exploration, there is an imperative to take the fruits of that exploration back to society as a whole. Just as we accept the idea that the research is not complete until the results are published, so should we accept the idea that the research is not complete until we have engaged the public in a discussion of the results and their meaning.

The need to take it back to the public complements the obvious need to explain to the public what science is and how it differs from, for example, religion. It is imperative that the public appreciates that the world is inherently understandable, that we can understand it by observing how it works, and that this process is what we call science. Recent actions in Kansas, for example, seem to argue that part of the public either does not understand this view of what science is or does not accept it. And, as a scientific community, we have to take our share of responsibility for the misunderstanding. After all, how many of us teach freshman-level university science courses as a collection of facts rather than as a way of thinking about the world?

Where do we go from here?

First, we need to understand the "sea change" in the role of science in society that has taken place in the last decade. We should not abandon doing the highest-quality science, but we do need to recognize that the societal drivers behind science, and the reasons for public support of science, have evolved. In particular, we need to recognize that the questions that the public is interested in are just as important and valid as the ones that interest the scientists, and that the scientific enterprise has to be done as a collaboration of scientists with the public.

We should take advantage of the tremendous public interest in high-visibility fields like planetary science, astrobiology, and cosmology. We should do this not just to shore up or increase our funding but, again, to use the interest in these fields to engage and educate the public about what science is. For example, we should emphasize in our teaching at all levels that, although science can be thought of both as a collection of facts and as a way of trying to understand the world around us, it is in this latter role that it makes its most significant contribution.

In fact, we can use these fields to help explore what the relationship is between science and society and what the role of science is in society today. We should both educate the public and the Congress and begin a dialog between scientists and the public about the nature of science. In the spirit of a true dialog, we should not just tell them what science is or why they should be interested in the questions that engage us; we need to learn from the public, and to work *with* them to determine what the goals should be.

We need to provide more than just lip service to the importance of outreach and education. This may be the hardest goal of all, as it requires a fundamental change in how we as scientists think about science. When we were in graduate school, we learned a lot about how to do science but very little about why we do science or about what value it has for society. We need to embrace the connections between science and society, and to value both the act of exploring those connections and the contributions of those who explore them.

Finally, discussion of the broader significance of science needs to be integrated into the educational process, into the scientific community, and into our science conferences. The A.G.U.,

with its biannual meetings that bring together thousands of scientists and are very inclusive of reporters, should be at the forefront of exploring what the role of science is in society today. We should have sessions on these issues, and invite colleagues from the humanities to discuss and debate them. And, we should attend and embrace those sessions!

We have tried here to put forward a self-consistent view of why we as a society engage in the scientific endeavor and why we as scientists are only a part of the process. Of course, we recognize that other issues are relevant and other viewpoints are valid. We welcome discussion of these issues, and of what our role as scientists is in this process.

References

(1) Bush, V., Science: The Endless Frontier, U.S. Govt. Printing Office, 1945.

(2) Ehlers, V., Unlocking our future: Toward a new national science policy, http://www.house.gov/science/science_policy_report.htm.

(3) Mission to the Solar System Roadmap, http://sse.jpl.nasa.gov/roadmap/index.html.

(4) Astrobiology Roadmap, http://astrobiology.arc.nasa.gov/roadmap.